

TECHNICAL REPORT 1916
July 2004

Distributed Information Systems for Maintenance and Safety

S. A. Murray

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SSC San Diego

| Report Documentation Page | | | Form Approved OMB No. 0704-0188 | |
|---|------------------------------------|---|---|----------------------------------|
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| 1. REPORT DATE JUL 2004 | 2. REPORT TYPE | 3. DATES COVERED 00-00-2004 to 00-00-2004 | | |
| 4. TITLE AND SUBTITLE Distributed Information Systems for Maintenance and Safety | | | 5a. CONTRACT NUMBER | |
| | | | 5b. GRANT NUMBER | |
| | | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) | | | 5d. PROJECT NUMBER | |
| | | | 5e. TASK NUMBER | |
| | | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) SPAWAR Systems Center ,SSC San Diego, San Diego ,CA,92152-5001 | | | 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited | | | | |
| 13. SUPPLEMENTARY NOTES | | | | |
| 14. ABSTRACT | | | | |
| 15. SUBJECT TERMS | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT Same as Report (SAR) | 18. NUMBER OF PAGES 45 |
| a. REPORT unclassified | b. ABSTRACT unclassified | c. THIS PAGE unclassified | | |

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SSC San Diego
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EXECUTIVE SUMMARY

A test and evaluation (effort or study) was conducted under the Tech Solution program of the Office of Naval Research to determine the feasibility and effectiveness of wireless wearable computing systems for support of aviation maintenance technicians. The body-worn information systems included electronic technical manual support, a virtual (i.e., software-emulated) test equipment suite, wireless voice communications, and Naval Aviation Logistics Command Management (NALCOMIS) database connectivity, coordinated over a wireless local-area network (LAN).

The program was conducted at Naval Air Station Brunswick between August 2002 and December 2003, and involved squadrons VP-10 and VP-26. Testing included objective (e.g., completion time, troubleshooting accuracy, etc.) and subjective (user evaluation) methods that compared performance between conventional tools and wearable computers.

Obtaining authorization to operate the wireless network in an operational facility was the most troublesome program issue, and delayed data collection considerably. Although the network was successfully installed, the delays exhausted project funding just as data collection began. although only limited user feedback was gathered, this information, was sufficient to make the following observations about wireless system use:

- Electronic maintenance manuals are useful, although no new insights were gained through their integration with wireless systems.
- Virtual test equipment and remote interaction with NALCOMIS are the two capabilities with the greatest potential for maintenance support over wireless networks.
- Wireless support may not require wearable computers; alternate information systems may be just as effective.

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BACKGROUND

The main purpose of Tech Solution 00039 was to demonstrate and evaluate an information system to support aviation maintenance. The proposed technical solution focused around a set of diagnostic, communication, and decision-support tools integrated into a portable computer, with collaboration support furnished through a wireless network. SPAWAR Systems Center, San Diego (SSC San Diego), in partnership with Bath Iron Works (BIW), initiated a project to satisfy the needs of the Office of Naval Research (ONR) Tech Solution through a program of software integration, structured field evaluation, and system definition to establish a foundation for service-level funding (i.e., program transition) of a distributed wireless wearable computing (WWC) information system.

Specifically, the project sought to examine knowledge extension (KE) through voice, video, and data exchange among aviation maintenance personnel using WWC systems hosting the following:

- Interactive electronic technical manuals (IETMs) that provide maintenance technicians with diagnostic, troubleshooting, and procedural task guidance at the work site. While IETMs are already deployed in units of the U.S. Navy and Marine Corps, their use on a personal, body-worn computer was new.
- Wireless communications tools (i.e., Voice-over-Internet Protocol [VoIP]) that permit real-time consultation with other technicians and hangar work centers without leaving the work site.
- Virtual test equipment (VTE) (i.e., measurement and diagnostic systems integrated into the WWC platform). The goal was to reduce the amount of support equipment that technicians were required to carry to the work site.

An additional objective cited in the original Tech Solution solicitation was to expedite fleet introduction of, and identify a funding path for, WWC and VTE technologies. Achieving this objective involved establishment of a technical context and business case for these technologies through comprehensive data collection and analysis.

Project issues surrounding design of the Tech Solution fell into two classes: programmatic and scientific.

PROGRAM ISSUES

System integration was addressed from the beginning of project design. While IETMs have a longer development history than WWC and VTE, electronic manuals can be even more effective when combined with these newer technologies. The need for the Tech Solution project was to ensure that WWC, VTE, and IETMs could be organizationally integrated into a coherent system of distributed information support.

The engineering process of implementing a wireless network, and quantifying its performance (e.g., establishing the reliability, signal coverage, and data loading characteristics) *in an operational environment* could guide the efficient deployment of future networks and lead to the realization of all the technologies that could ride on these networks. Wireless network security and integrity were appreciated even before work began. Information Technology (IT) managers throughout the Department of Defense (DoD) are extremely, and justifiably, sensitive to the need for data security over wireless or radio frequency (RF) communications networks. Although the Tech Solution project planned to use virtual private networks (VPNs) to provide needed security, the certification process that permits network operation was long and complex. The certification process formed a major component of the project design; team members understood that this process would limit development of the infrastructure on which the entire project depended.

Introduction of any new technology carries two implicit objectives: (1) to ensure that current users see its value (i.e., that users “buy in” to the technology), and (2) to ensure that a foundation for the future is laid through a mutual exchange of ideas between users and developers. Therefore, while the focus of the Tech Solution is to validate the utility of the WWC/VTE suite, the Tech Solution Team sought to exploit this opportunity to identify, structure, and prioritize issues for future technology development efforts.

SCIENCE ISSUES

The enterprise-level impact of WWC and VTE technologies is not well defined because little experience has been gained with either class of system. The science domain is wide open to new models of maintenance that can drive the effectiveness of these technologies when they are eventually deployed. For this reason, such issues represent a great transformational opportunity. While the current Tech Solution can only highlight the implications of these topics, and perhaps guide future work, such treatment fills many gaps that are not addressed in other maintenance support programs.

SSC San Diego approached the design of the Tech Solution project with a solid base of experience. As the primary human interface development laboratory for the Department of the Navy (DoN), SSC San Diego possessed extensive experience in design, execution, and analysis of user tests for new technologies. Specifically, SSC San Diego was involved in WWC for over 4 years, and has successfully executed funded projects involving the following:

- Hand-held, body-worn, and head-mounted (augmented reality) displays for mobile personnel support in indoor and outdoor environments
- Shipboard, shore-based, and field variants of robust wireless data networks, including electromagnetic interference (EMI) and security certification requirements
- Hands-free system interfaces incorporating voice and gesture control
- Electronic distance support for maintenance activities; SSC San Diego is currently involved in the Distance Support/Telemaintenance Advanced Concept Technology Demonstration (ACTD) program
- Electronic maintenance databases and information infrastructures; SSC San Diego manages several configuration and update projects for U.S. Navy IETM programs

The desired end-state of this Tech Solution was a clear implementation model backed up by a systematic, credible record of testing success.

METHOD

The Tech Solution implemented a fully functioning maintenance support system consisting of a set of wireless wearable computers—each containing an electronic maintenance manual, VoIP, and VTE subcomponents—integrated with a secure wireless network and usable throughout the entire range of squadron spaces (i.e., hangar, work centers, and flight line). Three performance topics were identified for study in order to develop a comprehensive characterization of the system—performance effectiveness, user evaluation, and engineering factors. The Tech Solution project used quantitative and qualitative measures. A self-reporting (user survey) method was used so that large data sets could be economically gathered during the study.

As described in the original Tech Solution proposal, performance metrics addressed hardware, software, and usability—with a clear emphasis on usability. Measurement topics were developed to include the following:

- Ease of equipment use (i.e., can the equipment be accessed and controlled alongside existing maintenance equipment and in the expected settings such as cockpits, flight lines, and workbenches?)
- Training time for operators and data analysts (e.g., how quickly can users become proficient? Can users retain that proficiency between shifts or tasks?)
- Efficiency and ease of access to support information (i.e., are the users getting the assistance they need from the WWC and its underlying information?)
- Ease of interaction under varying environmental conditions (e.g., indoor–outdoor, day–night, etc.)
- Effectiveness as a function of maintenance task (e.g., system specialty, task complexity, etc.)
- Reach-back effectiveness (i.e., work center, database, and team member interaction effects)
- User acceptance and suggestions for changes/improvements (we were looking for problem solutions as well as ideas for new applications or features)
- Quantitative measures of time and accuracy (used for analyses of potential cost savings)

PERFORMANCE EFFECTIVENESS

The fundamental contribution that the Tech Solution can provide to the U.S. Navy is quantitative metrics regarding the performance effectiveness of the system (and/or its components). These metrics involve:

- Time to complete a task
- Frequency of face-to-face (versus on-site) interactions with supervisors or work centers to complete problem analyses
- Time spent obtaining tools to complete a task after the problem has been diagnosed

Reductions in any or all of these metrics would demonstrate the potential utility of the WWC solution. The Tech Solution plan called for generation of a baseline data set for these metrics collected from technicians using conventional methods and tools, compared with a later, matched data set collected from technicians using WWC support.

USER EVALUATION

Some characteristics of technology—and the impact they have on work practices—cannot be identified with observable performance metrics; user opinion is then used as a method for evaluating the “intangibles.” While the U.S. Navy requires clear performance benefits from a new technology to justify acquisition, user acceptance of the technology is still necessary or it will not be used. Therefore, the Tech Solution project includes a user evaluation survey to solicit judgment data from technicians employing WWC. To capture any changes in opinion owing to increasing familiarity, this survey was designed for use at the beginning and end of the study.

ENGINEERING FACTORS

The process required to instantiate a functional, secure wireless network at an operational military facility is not clearly defined, owing to the fluctuating guidance emerging throughout DoD IT agencies. This climate, in turn, is complicated by the heightened concern for data security following 9/11, by the poorly understood effects of operational wireless communications transmissions and the abundance of devices (e.g., cell phones, personal digital assistants [PDAs], etc.) that use them, and the emerging procedural complications associated with the Navy-Marine Corps Intranet (NMCI). The known steps required to establish an approved network at the test site (Naval Air Station [NAS] Brunswick) included:

- Completing a physical, electrical, and environmental survey of the hangar and squadron spaces used for the Tech Solution test
- Developing and documenting a security policy (a System Security Authorization Agreement [SSAA]) and obtaining approval of the plan
- Obtaining written command approval for network operation from the IT offices of CPRW-5, NAS Brunswick, and Navy Region North East (CNRNE) to include Interim Authority to Operate (IATO) certification
- Obtaining system safety certifications (e.g., EMI and Hazards of Electromagnetic Radiation to Ordnance [HERO] inspection documents)
- Developing a plan for storing, accounting for, and maintaining WWC units in the hangar spaces

Because an effort like this had not been attempted before, the design and authorization process developed as the project evolved. The data for this aspect of the work were therefore descriptive, and the result of this effort was a procedural “go by” with appropriate “lessons learned” for future network installations.

The original Tech Solution proposal specified a review of multiple systems (e.g., PDAs, laptops) to establish a scale for evaluating WWC performance against alternative technologies. This topic was addressed through selective questions in the User Evaluation surveys (described below) to determine which performance gains (if any) were realized through the overall network solution and which were unique to the WWC systems. In particular, items such as 3 and 4 of the WWC/VTE System Evaluation (Appendix A-1) were included in the survey instruments to solicit user reaction to these issues. In addition, hardware and software performance characteristics (e.g., battery life, weight, application reliability, etc.) are necessary and critical metrics to any evaluation of a new technology. User opinion on these factors was solicited through such items as 1, 2, 9, and 10 in the survey.

PROTOCOL

The data collection procedure was executed according to the following protocol. Figure 1 shows the WWC system configuration used for this project.

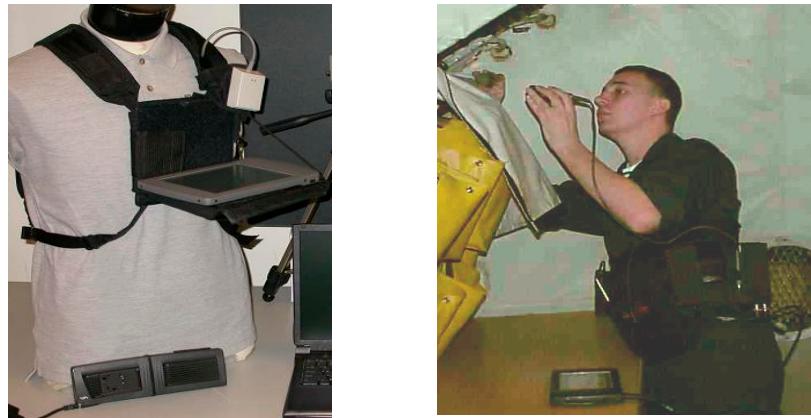


Figure 1. WWC configuration for maintenance support.

Initial Interviews

The WWC/VTE System Evaluation (Appendix A-1) was designed to gather user reaction information regarding the WWC and its utility. This report was first administered to prospective WWC users as soon as their training was completed to establish an opinion baseline. An interviewer from SSC San Diego or Bath Iron Works (BIW) went over the form with each user to make sure that users understood the questions. These reports took approximately 20 minutes to complete.

Baseline Performance Characterization

Maintenance personnel were instructed to complete a Maintenance Task Results report (Appendix A-2) at the conclusion of every maintenance action. Personnel were trained in how to use this form before first use, and the data generated over a 5-week period were gathered to establish a performance baseline of maintenance actions using conventional methods. Participants could complete the form in about 3 to 4 minutes, with minimal interference with operational job duties. These forms were gathered and maintained by Squadron Maintenance Control for weekly pickup by BIW personnel.

On-the-Job WWC Use

Once maintenance personnel had been trained in WWC use and had completed an initial WWC/VTE System Evaluation, users were trained in how to use the WWC/VTE Results report (Appendix A-3). Participants could also complete this form in less than 4 minutes. Once WWC systems were in use, technicians were asked to complete a Maintenance Task Results report and a WWC/VTE Results report for every job where WWC was used. The WWC/VTE Results report included survey items unique to the performance of the technology (e.g., its availability, utility, specific strengths and weaknesses in the context of the maintenance task, etc.). These forms were gathered and maintained by Squadron Maintenance Control for weekly pickup by BIW personnel.

Late-Term Interviews

The WWC/VTE System Evaluation was administered for each technician approximately 8 weeks after WWC use began (for that individual).

Post-Session Interviews

After all data were collected, a final exit interview was administered to identify issues, concerns, and/or suggestions by individuals that did not find their way onto the survey instruments. All reports and interviews were examined for trends as a function of on-the-job experience with the system.

Because BIW and its partners provided the technologies for this Tech Solution, SSC San Diego acted as the impartial evaluator for data collection and analysis. SSC San Diego did, however, assist with user orientation and training to ensure that the data collection effort got off to a sound start, and supplemented the study with on-site visits at selected intervals in the project preparation and data collection process.

RESULTS

The Tech Solution project began in August 2002 and ended in September 2003.

OVERVIEW

The project was initiated in August 2002 after a contract award to BIW, and baseline data collection began the same month. Engineering installation of the wireless network commenced in October 2002 in parallel with certification efforts. Interagency discussions and policy setting delayed submission of certification documents until Winter 2003. Authority to operate was not received until early summer. WWC training began immediately, and data collection commenced in July. Funding resources were depleted in September, but data collection continued until the project concluded in November. The following sections summarize the major milestones of the Tech Solution project.

TIMELINE

| | | |
|-----------|------|---|
| March | 2002 | SSC San Diego Tech Solution proposal submission |
| April | 2002 | BIW response to Tech Solution request for proposal (RFP) |
| August | 2002 | BIW Tech Solution contract award |
| August | 2002 | Baseline Job Report data collection from VP-10 |
| October | 2002 | BIW Site Survey Report |
| October | 2002 | BIW System Design Document |
| December | 2002 | HERO certification |
| March | 2003 | SSAA submission to CPRW-5 |
| April | 2003 | IATO document submission |
| May | 2003 | EMI effects approval |
| May | 2003 | IATO endorsement by Naval Network Warfare Command (NETWARCOM) |
| June | 2003 | IATO approval by CPRW-5 (6 months of operation) |
| July | 2003 | WWC General System Form initial data collection at VP-26 |
| September | 2003 | Project funding depleted |
| November | 2003 | WWC General System Form final data collection |
| December | 2003 | Final data set delivery to SSC San Diego |

Difficulties in obtaining permission to operate the wireless network drove the project schedule. The Tech Solution was executed during administrative confusion regarding DoD security policy, which was undergoing discussion and debate, with multiple agencies taking precautionary positions of delay while service-wide guidance was generated. In addition, NMCI transition was initiated at NAS Brunswick during this time, and uncertainty regarding its implications exacerbated the approval process. The practical affect of these problems was that each level of the approval chain hesitated to commit to an authorization strategy, reluctantly exercised an authorization strategy, or overtly resisted the project entirely. Consequently, considerable effort was expended in working the

authorization request through the command chain. Permission to operate the network was not obtained until June 2003.

As shown in the timeline, WWC data collection efforts began as soon as authorization was received. Although the startup process encountered the kinds of technical difficulties typical of research efforts, and some weeks were spent in debugging the hardware and the software, data collection was conducted when the system was available. Given the protracted interval involved in the authorization process, however, and the extensive manpower commitments required to define and complete it, the project became funding-limited. Support for the project ended in September 2003. The Tech Solution effort concluded its final data collection efforts. ONR instructed the project to assign responsibility for the WWC equipment to the squadron.

PERFORMANCE EFFECTIVENESS

The Tech Solution protocol measured WWC system performance effectiveness by comparing two groups: technicians using conventional maintenance methods (members of Squadron VP-10) and technicians using WWC and VTE support. As Appendix A-2 shows, the following performance metrics were included:

- Time to complete a task, categorized by
 - Type of task
 - Location (e.g., hangar, flight line)
 - Time of day
 - Technical rate(s) performing the job
- Tools required (to assess the utility and desired future capabilities of VTE)
- Transit required (i.e., consultation trips back to the work center or Maintenance Control (which could be reduced through WWC communications)

The baseline data set, representing conventional maintenance methods, was collected from members of VP-10. Over a 5-week period, 241 Maintenance Task Results reports were gathered from eight technical rates.

As mentioned earlier, the WWC break-in period at VP-26, July–September 2003, encountered technical difficulties that made WWC availability intermittent. Furthermore, the command insisted, and the Tech Solution Team agreed, that a wireless connection to NALCOMIS (the electronic maintenance action recording system) was necessary to fully exploit WWC applications. Integration and validation of this feature took additional time away from WWC availability. The team declined to collect Maintenance Task Results data during this interval, choosing instead to wait until WWC systems could be used reliably on a regular basis (where the data would be more accurate and more meaningful). Unfortunately, project funding was depleted before this data collection could begin. As a result, no comparison data were available to complete this portion of the project analysis.*SSC San Diego retained baseline data, however, pending any future effort to measure WWC on-the-job performance.*

USER EVALUATION

In July 2003, the Tech Solution Team collected WWC/VTE System Evaluations from 16 Aviation Electronics (AT) technicians, the first group of WWC-trained personnel at VP-26. These data represent user judgments about WWC and VTE after system orientation, but *before* on-the-job use.

The objective of this survey was to gather “first-look” evaluations that could then be compared with identical surveys collected 6 to 8 weeks later, after extended use.

Again, technical difficulties in implementing regular WWC functionality and delays to accommodate NALCOMIS functionality interfered with the development of a solid base of user experience. Final administration of the WWC/VTE System Evaluation (from 14 technicians) was not completed until the end of October 2003, an interval of approximately 16 weeks. The results of both surveys, including comments from the personnel who completed the forms are in Appendix A-1.

Interpreting responses from such a small group is difficult; individuals with strong opinions can influence the final scores, when averaged. Nevertheless, the following useful observations could be made from these data:

- The WWC system is light, but possibly too bulky (note that design changes since this Tech Solution was conducted may have already improved this condition).
- System reliability made an impression on the users; the technical difficulties in standing up the full WWC capability, including NALCOMIS, made it difficult for users to establish a consistent perspective on equipment operation.
- The WWC display was usable, but a tablet display might be preferable.
- Connecting WWC/VTE capability to other equipment might be useful.
- The potential for VTE was seen as positive; NALCOMIS connectivity is essential.
- IETM navigation could be improved.

Although the case for using a body-worn computer for maintenance support was not made in this study, the results must be viewed with caution, as users had relatively little experience with the equipment before the termination of the project. It was clear from the user responses, however, that mobile (wireless) electronic tools had positive value.

ENGINEERING FACTORS

The engineering process needed to realize that the WWC system could be divided into two parallel phases: technical and administrative. The technical tasks involved in the Tech Solution are detailed in the following six documents:

1. Site Survey for Naval Air Station Brunswick VP-8 Wireless Maintenance Network, 10–11 October 2002. This document presents all steps needed to ensure signal coverage throughout squadron workspaces and optimal placement of wireless access points. Contact A. J. Ballard at 207-442-5264 or Brian D. McCue at 207-447-2803 for information about acquiring this document.
2. System Design Document for Naval Air Station Brunswick Hangar 5 Wireless Maintenance Network, 23 October 2002. This document contains the wireless system operating concept, physical layout, hardware and software components, and installation descriptions. Contact A. J. Ballard at 207-442-5264 or Brian D. McCue at 207-447-2803 for information about acquiring this document.
3. Hangar 5 Network Plan (Figure B-1). This figure details the physical placement locations of all network components.
4. Hangar 5 VPN Diagram (Figure B-2). This document depicts the physical configuration of the virtual private network for the test site.

5. WWC System Specification. Pen Systems provides the technical characteristics and physical configuration of the WWC unit at the following website: <http://www.pensystems.com/specs.htm>
6. Getting Started With VirtualBench™. This National Instruments® document details the core software package for supporting VTE functions on the WWC. The document is available at the following website: <http://www.ni.com/pdf/manuals/321518e.pdf>

Configuration of the wireless network and VPN layer were completed with support from Cisco Systems, Inc., a BIW partner for this project. Cisco® components were used extensively in the network implementation. WWC functionality—particularly VTE features—was realized with the assistance of National Instruments® software and expertise.

Obtaining official approval to operate the WWC system required planning for safety and security concerns. The key steps in this effort are summarized in the following four documents:

1. HERO Approval for Wireless Local Area Network At Naval Air Station Brunswick Maine (Appendix C-1). This document confirms that analysis of network operation presented no hazards of electromagnetic radiation to ordnance.
2. System Security Authorization Agreement for the Hangar 5 Wireless Maintenance Network Naval Air Station Brunswick, 26 March 2003. This document contains a complete analysis of the physical, organizational, and procedural plans to ensure secure operations of the wireless network, hosted on the NAS Brunswick IT backbone. For information about acquiring this document, contact:

Commander, Patrol & Reconnaissance Wing Five
5 Jay Beasley Circle
Naval Air Station Brunswick
Brunswick, ME 04011

3. Electromagnetic Environmental Effects (E³) Review of the Site Approval Request for Installation of a Cisco Wireless Local Area Network at Naval Air Station Brunswick Maine. This document confirms the results of an analysis that the wireless network presented no electromagnetic interference hazards. For information about acquiring this document contact:

Space and Naval Warfare Systems Center, Charleston
P. O. Box 19022
North Charleston, SC 29419-9022

4. Interim Authority to Operate Sensitive But Unclassified Wireless Information System (Appendix C-2). This document provides the final step in official approval to operate the network.

As described earlier, the approval process was complicated by the period in which the Tech Solution project took place, a time when DoD was addressing the security issues of wireless networks and attempting to generate guidance documents. The climate was characterized by extreme caution. Final approval provided authority to operate the network at the test site through December 2003. The additional complications of early NMCI installation steps at NAS Brunswick entailed additional (yet, poorly defined) constraints. The naval air station now operates under NMCI, so new operating authority must be processed under additional rules.

The efforts of the Tech Solution Team were largely invested in obtaining authorization to perform the WWC tests (i.e., to operate a wireless network). This investment, however, has generated a procedural and technical “road map” for future efforts involving operational use of wireless technologies. At the conclusion of the Tech Solution project, all physical property was assigned to the host squadron, VP-26.

DISCUSSION

Two benefits were gained from this Tech Solution: (1) understanding of the process for implementing operational wireless networks has grown much more sophisticated and realistic as a result of the lessons learned at NAS Brunswick, and (2) a better perspective was gained about how to design portable maintenance support systems (i.e., alternatives to wearable computers) as a result of user interviews and surveys.

The inability to gather performance data severely limited the utility of the Tech Solution project. The preparation efforts necessary to stand up an operating wireless network were difficult, and most of the obstacles encountered were either unexpected or beyond the control of planners. As mentioned earlier, the baseline performance data were retained for possible use in future efforts to measure performance gains from maintenance support technologies, but this future use is all that can be expected from the performance measurement thrust of the project.

Once configured, authorized, and activated in July 2003, the WWC system performed flawlessly from a hardware standpoint. Signal coverage of the hangar and flight line were continuous throughout the Tech Solution test.

Most of the difficulties encountered involved software configuration. Factors that limited the quality of data collection included the following conditions:

- Problems with NALCOMIS software operation with wireless devices; NALCOMIS was designed to work with older UNIX-based programs. Differences between the scan codes of a physical keyboard (which NALCOMIS software was designed for) and the wearable computer touch-screen keyboard were very difficult to overcome. While this problem was addressed, technicians were unable to perform their jobs with WWC and interact with NALCOMIS, as required by their duties. During this period, collection of Maintenance Task Results data was impossible. BIW attempted to obtain an updated release of the touch-screen software, but project funding was exhausted.
- For security, the project's infrastructure was not allowed access to a key base router. Access to this critical router was required by the wearable computer network for the base Domain Name Server (DNS) to respond to the wireless network. Several weeks were lost attempting to determine why the wireless network was having DNS-related issues. During this period, it was not possible to log into the base IT system to access working directories. With no access to working directories, squadron personnel could not effectively use the wearable computers.
- Time was lost in gaining permission to modify the router table with a pointer to the wireless network (to address the router IP table issue) due to NAS Brunswick security concerns. In addition, the static IP route addition to the single router could not be effectively managed at the level of NAS Brunswick, as all of their router updates are the secure global variety.
- The wireless network was down for several weeks after an NMCI upgrade was applied to the base routers. This change was implemented without warning to the Tech Solution Team or the squadron.
- Additional downtime resulted from the release of several U.S. Navy IT change notices. Compliance with these directives required the acquisition of software upgrades for the wireless network. Project funding was exhausted by the time all the new software was obtained.

- A training/skill issue arose during the test, as instances were found where squadron technicians inadvertently corrupted some WWC settings. These problems had to be painstakingly tracked down and fixed, reducing time for system operation and data collection.
- Command reluctance to use the wireless network without NALCOMIS was made clear to the team. Nevertheless, WWC support for NALCOMIS was not part of the original Tech Solution Statement of Work. Several weeks were lost in attempting to understand and implement NALCOMIS to satisfy squadron requests.

In summary, significant technical experience was gained in the effort to establish a wireless network in an operational military setting. The benefit from lessons learned through this effort should not be underestimated; the knowledge gained will benefit future projects to introduce new technologies involving distributed personnel and a common communications/ data infrastructure.

Good, if limited, information was gained from soliciting user reactions to the WWC technology concept. While complete faith should not be placed in such a small data set, the trends in these data were enlightening regarding the utility of VTE systems and the best way to present information in future efforts (e.g., tablets or other hand-held devices). Subsequent efforts to provide distributed maintenance support should include a range of computing systems *in addition to* (because the case is, as yet, still unclear) wearable computers.

TRANSITION

Representatives of Space and Naval Warfare Systems Command (SPAWAR) and Naval Air Systems Command (NAVAIR) have been contacted regarding the process for transitioning products of this Tech Solution to program-of-record status. While these procedures are understood, a necessary precursor to further action is the documentation of requirements, beginning with endorsements from user communities. Given the current lack of documented performance data and the limited user experience with the system, serious pursuit of transition opportunities without further testing is not recommended.

SUMMARY

This report has presented evidence to justify the following primary lessons from the Tech Solution project:

1. The method for designing and implementing a wireless network at an operational command is understood and validated.
2. Electronic maintenance manuals are useful, although no new insights were gained through their use with WWC systems.
3. Virtual test equipment and remote interaction with NALCOMIS are the two capabilities with the greatest potential for maintenance support over wireless networks.
4. Wireless support may not require wearable computers; alternate information systems may be just as effective.

Insufficient data were collected to provide a foundation for technology transition; additional performance data are needed before operational endorsements or statements of requirements can be solicited.

APPENDIX A

APPENDIX A-1

WWC/VTE SYSTEM EVALUATION

Notes:

1. Large X = average of original survey respondents
2. Small X = average of final survey respondents
3. Specific averages (original and final) are found below the scale for each item
4. Comments from technicians are from final survey only; no comments were generated during original survey.
5. Most comments came from a single individual (AT2)

GENERAL CHARACTERISTICS

1. This equipment is

| | |
|-----------------------|-----------------|
| Too heavy | Light enough |
| ----- ----- ----- | X-X----- ----- |

for regular individual use

Original rating average = 2.6; final rating average = 2.7

Comments:

Light enough, but too bulky for practical use

2. This equipment is

| | |
|------------------------------|----------------|
| Too bulky | Compact enough |
| ----- ----- X----- ----- | |

for regular individual use

Original rating average = 2.3; final rating average = 1.7

Comments:

Hampers more than it helps

3. The WWC system is at least as reliable as any other maintenance equipment I use

| | | |
|------------------------------|------------|-------------------|
| Strongly agree | No opinion | Strongly disagree |
| ----- ----- X----- ----- | | |

Original rating average = 2.0; final rating average = 2.4

Comments:

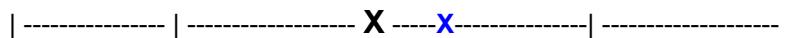
Functionality is always questionable; Software is big issue; LAN connection is spotty at best

4. The VTE system is at least as reliable as any other maintenance equipment I use

Strongly agree

No opinion

Strongly disagree



Original rating average = 2.0; final rating average = 2.3

Comments:

VTE is the best concept of the system; saves us time and saves the Navy money

5. All parts of this equipment (e.g., controls, leads, etc.) are easy to reach when I need them

Strongly agree

No opinion

Strongly disagree



Original rating average = 2.0; final rating average = 1.8

Comments:

Layout is decent. Belt and shoulder harness get in the way of maintenance. Meters are nice if user is properly trained.

Didn't have a complete vest with oscilloscope card or anything.

6. I think that all parts of this equipment are easy to stow on the vest when I don't need them

Strongly agree

No opinion

Strongly disagree



Original rating average = 2.0; final rating average = 1.8

Comments:

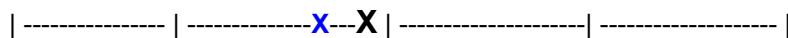
Plan is good; actual use is cumbersome.

7. I think that this equipment is easy to store in the work center between uses

Strongly agree

No opinion

Strongly disagree



Original rating average = 1.9; final rating average = 1.7

Comments:

Weren't allowed to store them in the work center.

8. I think that this equipment is rugged enough to function under all operational maintenance conditions

Strongly agree

No opinion

Strongly disagree

| ----- | ----- X -----| ----- |

Original rating average = 2.0; final rating average = 2.3

Comments:

9. I think that the battery life is sufficient for completing most jobs

Strongly agree

No opinion

Strongly disagree

| ----- | ----- X -----| ----- |

Original rating average = 2.0; final rating average = 1.8

Comments:

10. I think that the battery is easy to replace when needed

Strongly agree

No opinion

Strongly disagree

| ----- | ----- X -----| ----- |

Original rating average = 2.0; final rating average = 1.5

Comments:

DISPLAY CHARACTERISTICS

1. I can see the display surface under all conditions

Strongly agree

No opinion

Strongly disagree

| ----- | ----- X-----| ----- |

Original rating average = 2.1; final rating average = 2.3

Comments:

2. I think that the display can be used during work without unnecessarily tying up my hands

Strongly agree

No opinion

Strongly disagree

| ----- | ----- X-----| ----- |

Original rating average = 2.0; final rating average = 2.1

Comments:

Tablet display would be better (that we could set down). We have no need to actually wear the computer.

3. I can read the text information on the display under all conditions

Strongly agree No opinion Strongly disagree

| ----- | ----- | X-X-----| ----- |

Original rating average = 2.1; final rating average = 2.3

Comments:

4. I can read the graphical information (i.e., symbols, figures) on the display under all conditions

Strongly agree No opinion Strongly disagree

| ----- | ----- | X-X-----| ----- |

Original rating average = 2.1; final rating average = 2.3

Comments:

5. I think that color is useful for reading the display

Strongly agree No opinion Strongly disagree

| ----- | ---X-----X | ----- |

Original rating average = 1.9; final rating average = 1.3

Comments: 1.9 1.3

6. I would suggest the following changes to improve the physical display:

No comments to this item

7. I would suggest the following changes to improve the information on the display:

Better software functionality

8. I think that the system controls provide enough range to adjust the display under all conditions

Strongly agree No opinion Strongly disagree

| ----- | ---X-X-----| ----- |

Original rating average = 2.0; final rating average = 1.9

Comments: 2.0 1.9

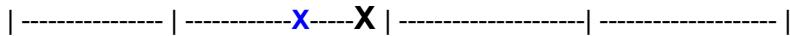
9. I would suggest the following changes to the display controls (e.g., thumbwheels, pushbuttons, knobs, different ranges of adjustment, functions, etc.):

No responses to this item

SYSTEM CHARACTERISTICS

1. I think that the system should be able to utilize aircraft displays by tying into aircraft access points

Strongly agree No opinion Strongly disagree



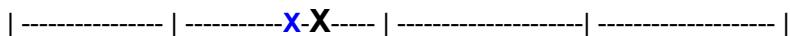
Original rating average = 1.9; final rating average = 1.6

Comments:

Doesn't seem necessary for our purposes

2. I think the system should be able to connect and use other devices (e.g., conventional test equipment, other data terminals, etc.)

Strongly agree No opinion Strongly disagree



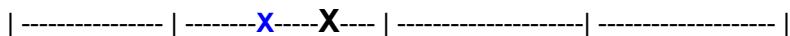
Original rating average = 1.7; final rating average = 1.6

Comments:

This is one of the best functions of this system. Integration of equipment we use could save us time.

3. Self-calibration is an important and useful feature of the VTE subsystem

Strongly agree No opinion Strongly disagree



Original rating average = 1.8; final rating average = 1.5

Comments:

Self calibration makes everything easier.

4. I would make the following suggestions to improve the features (e.g., controls and peripheral devices) of the WWC system

Just give us tablets. We have no need to wear the computers; not wearing them would increase their use exponentially.

NALCOMIS

5. I would make the following suggestions to improve the features (e.g., controls and peripheral devices) of the VTE subsystem

VTE is very nice and effective

ELECTRONIC MAINTENANCE MANUALS

Navigation

1. The controls are effective and appropriate for finding the manual pages I need

Strongly agree No opinion Strongly disagree

| ----- | ----- X -X -----| ----- |

Original rating average = 2.0; final rating average = 2.1

Comments:

2. I can locate the manual pages I need quickly

Strongly agree No opinion Strongly disagree

| ----- | ----- X -X -----| ----- |

Original rating average = 2.0; final rating average = 2.1

Comments:

3. I always know where I am in the manual

Strongly agree No opinion Strongly disagree

| ----- | ----- X -X -----| ----- |

Original rating average = 2.0; final rating average = 1.8

Comments:

4. The best feature to help me navigate through the manuals is

Windows / Adobe reader
Index

5. The worst navigation feature is

Getting used to the electronic keyboard

6. I suggest the following changes to better help me navigate through the manuals (e.g., controls, label information, etc.)

No responses to this item

Display

7. I like the way that information is organized and presented on the display; pages are divided up in a logical manner

Strongly agree No opinion Strongly disagree

| ----- | ----- **X** ----- | ----- |

Original rating average = 2.0; final rating average = 1.8

Comments:

8. I can read the graphical information (e.g., diagrams and charts) without difficulty while doing my job

Strongly agree No opinion Strongly disagree

| ----- | ----- **X** ----- | ----- |

Original rating average = 2.0; final rating average = 1.8

Comments:

9. The best feature of the manual display is

Size and visibility

10. The worst feature of the manual display is

It's attached to the user's body (totally unnecessary)

11. I suggest the following changes to improve the display of maintenance manuals

More accessibility to updated pubs

Content

12. The manuals I use have all the material I need to support my job performance

Strongly agree No opinion Strongly disagree

| ----- | ----- **X** ----- | ----- |

Original rating average = 2.0; final rating average = 1.9

Comments:

13. I'd also like to see the following support documents available on this system (e.g., NATOPS, MIMS, etc)

Comprehensive pubs are vital.

ALL

CSMM's

14. I suggest the following changes to the content of these manuals to better help me do my job (e.g., functionality, content, web browsing, etc.)

Different systems

Data Access Strategy

15. Manuals and other documents should be

2 loaded on the wearable computer

2 accessed from a central database, to be viewed on the wearable computer

2 a combination of both, depending on the job

Note: only six people responded to this item

APPENDIX A-2

MAINTENANCE TASK Results

1. **Where** was this job primarily performed?

flight line hangar work center

2. **When** was it performed?

day night dawn / dusk

3. **What** were you asked to do?

4. This task was preventive maintenance unscheduled maintenance

5. **What** did you need to accomplish to complete this job?

Test equipment _____

Manuals _____

Parts _____

Other _____

6. What was the outcome of this job?

Complete AWM AWP Other (please specify: _____)

7. How much time did you spend on this job (you can record start/stop times if you like)?

8. Did you need to work with other technicians to complete this job? If so, who (i.e., rating and rate)?

9. Did you need the help of your supervisor to complete this job?

10. Did you need to return to your work center while performing this job? If so, how many times?

Why?

APPENDIX A-3

WWC/VTE RESULTS

_____ The system failed during this job

Nature of failure:

1. _____ I needed to replace the battery before starting this job
2. _____ I needed to replace the battery during this job
3. Please mark your best judgment regarding the usefulness of the WWC/VTE system for this job –

Ineffective /
wasteful

the same as
working manually

Productive /
helpful

| ----- | ----- | -----| ----- |

4. The most effective/productive feature of this system (for this job) was –
5. The least effective/productive feature (for this job) was –
6. Other comments about the performance or usability of the WWC/VTE system (for this job) –
7. I would suggest the following changes to improve the WWC/VTE –

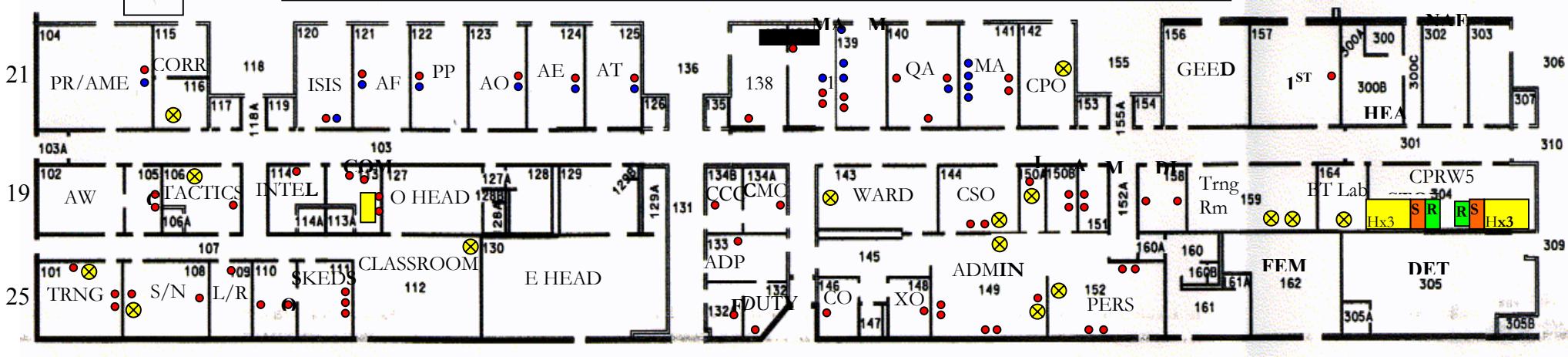
APPENDIX B

Hangar 5 South Cat5 drop diagram

Drops placed in middle of wall or follow old wiring placement, whichever is easier. Both Red & Blue dots = Cat5, but designate separate LAN's eventually. Diagrams are not all to scale, and should be used for placement data only.

Admin LAN ● (Red)=65, Nalcomis LAN ● (Blue)=17, Router (R)=2, Switch (S)=2, Hub (H)=7.

Yellow X = requested extra drops if material is left over after primary job, total 14

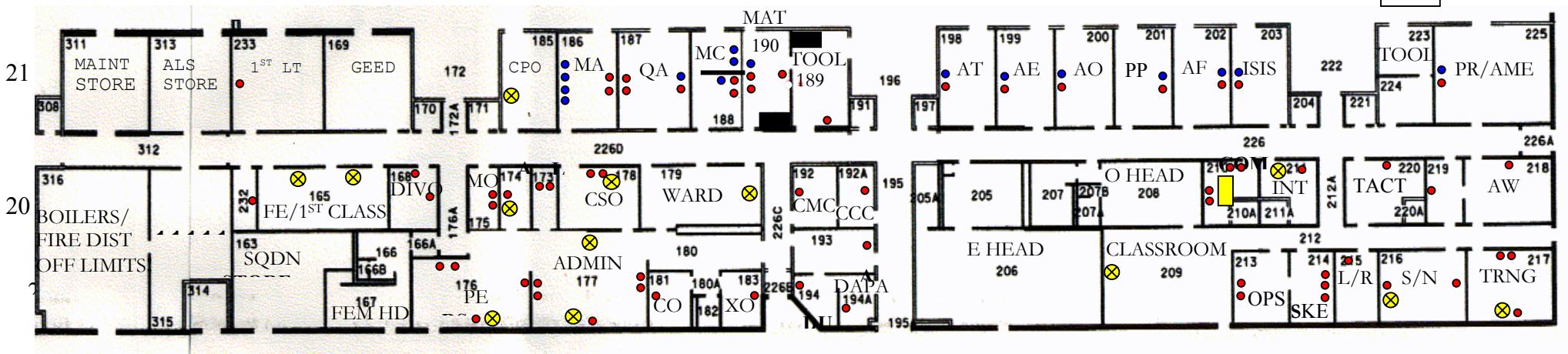


Hangar 5 North Cat5 drop diagram

Drops placed in middle of wall or follow old wiring placement, whichever is easier. Both Red & Blue dots = Cat5, but designate separate LAN's eventually. Diagrams are not all to scale, and should be used for placement data only.

Admin LAN ● (Red)=66, Nalcomis LAN ● (Blue)=17, Hub (H)=1.

Yellow X = requested extra drops if material is left over after primary job, total 13



**CPRW-5
Virtual
Private
Network**

(205.69.xxx.xx)

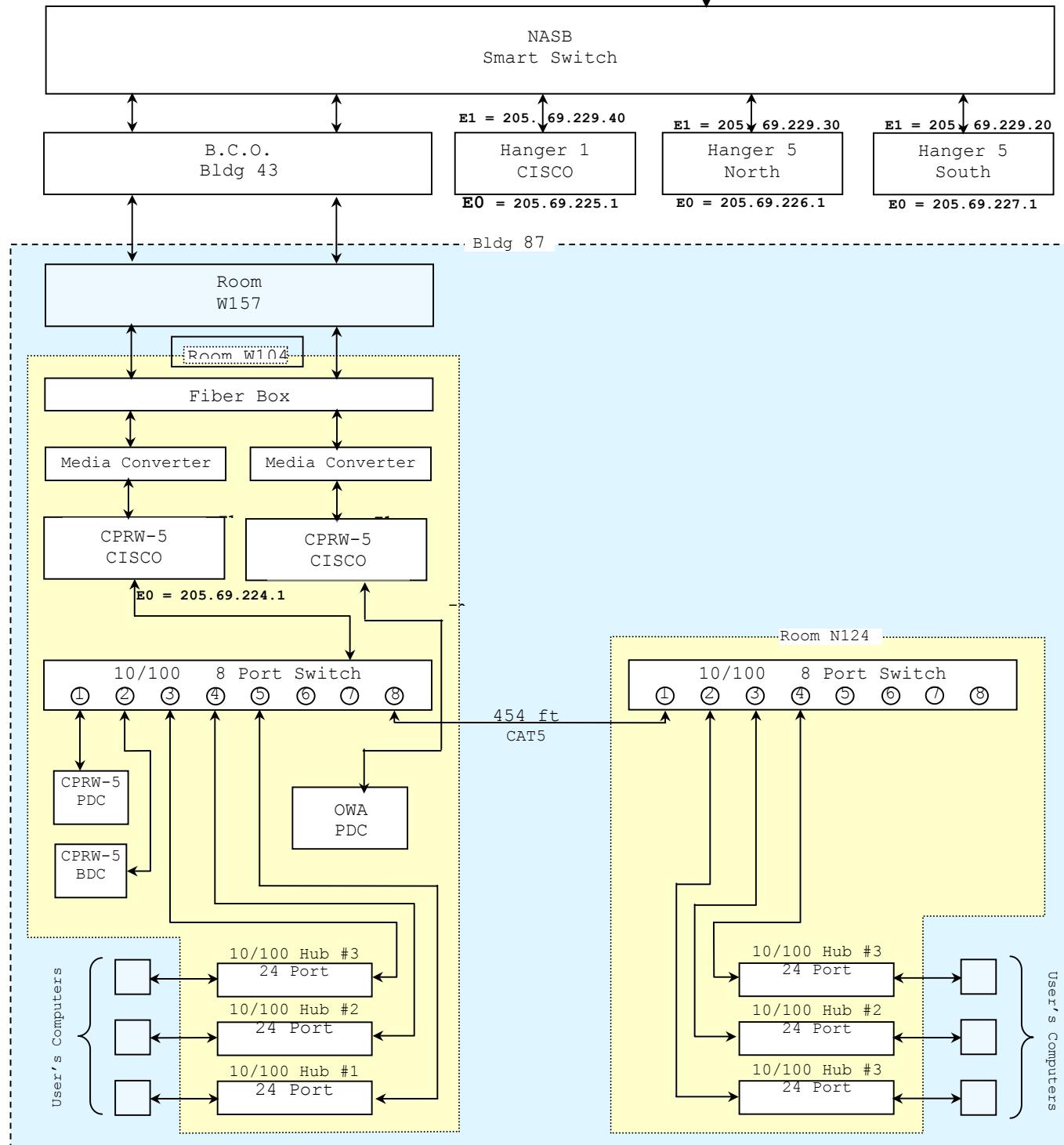
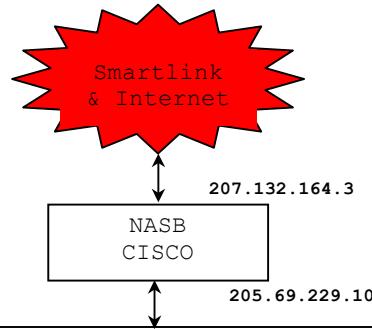


Figure B-2. Hangar 5 Cat5 drop diagram (Top: South; Bottom: North)

APPENDIX C

APPENDIX C-1



DEPARTMENT OF THE NAVY NAVAL ORDNANCE SAFETY & SECURITY ACTIVITY FARRAGUT HALL BLDG D-323 23 STRAUSS AVENUE INDIAN HEAD MD 206404555

8020
Ser N7162/1422
December 2, 2002

B. McCue
Bath Iron Works
700 Washington Street
Bath, ME 04530-2556

Dear B. McCue:

SUBJECT: HERO APPROVAL FOR WIRELESS LOCAL AREA NETWORK AT
NAVAL AIR STATION BRUNSWICK MAINE

In accordance with NAVSEA OP 3565/NAVAIR 16-1-529, Volume 2, Eleventh Revision, a Hazards of Electromagnetic Radiation to Ordnance (HERO) analysis was conducted to determine the impact of installing and utilizing a Wireless Local Area Network (WLAN) in Hangar 5 at Naval Air Station Brunswick, Maine. The purpose of the analysis was to determine if this installation has any adverse impact upon local ordnance items. New installations, such as WLAN's with access point transceivers and client adapter network cards can affect the electromagnetic environment and have adverse impact on ordnance items within the area.

The analysis detailed in enclosure (1) indicates HERO issues will not be a concern for the antenna of the fixed access points; however, HERO Emission (EMCON) control will be required for the client adapters. The EMCON requirement will be to maintain a safe separation distances when HERO UNSAFE or HERO SUSCEPTIBLE ORDNANCE is within the area. If the distance cannot be maintained then the offending client adapter must be silenced. The required safe separation distances are listed in enclosure (1)

HERO approval is granted for this installation provided the safe separation distances specified in enclosure (1) are maintained.

Sincerely,

G. FRIEDMAN
Commander, U.S. Navy
Director, Explosives Safety and
Security
By direction of the
Commanding Officer

HS00944

8020
Ser N7162/1422
December 2, 2002

Enclosure: 1. NAVSURFWARCENDIV Dahlgren ltr 8020 Ser J52/1288
Of 21 Nov 02

copy to:
NAS Brunswick (Safety Officer, GEMD)
NOSSA ESSOLANT (N7L)
NAVSURFWARCENDIV Dahlgren (J52/Denham)
EG&G Dahlgren (E. Kuhn, D. Willis)



DEPARTMENT OF THE NAVY

NAVAL SURFACE WARFARE CENTER
DAHLGREN DIVISION
17320 DAHLGREN ROAD
DAHLGREN, VIRGINIA 22448-5100

IN REPLY REFER TO
8020
Ser J52/1288

NOV 21 2002

From: Commander, Dahlgren Division, Naval Surface Warfare Center
To: Commanding Officer, Naval Ordnance Safety and Security
Activity
(N716/C. Wakefield)
Farragut Hall, Bldg. D323
23 Strauss Avenue
Indian Head, MD 20640-5555

Subj: HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO) ANALYSIS FOR THE INSTALLATION OF A WIRELESS LOCAL AREA NETWORK (WLAN) IN HANGAR 5 AT NAVAL AIR STATION (NAS) BRUNSWICK, MAINE

Ref: (a) NAVSEA OP 3565/NAVAIR 16-1-529, Volume 2, Eleventh Revision of 1 May 02
(b) E-Mail Bath Iron Works, B. McCue/EG&G Technical Services, Inc., R. Mersiowsky of 6 Nov 02
(c) NAVORDCEN ltr 8020 Ser N7132/215 of 28 Mar 97

Encl: (1) System Specifications and Hazards of Electromagnetic Radiation to Ordnance Safe Separation Distances
(2) Hangar 5 Wireless Local Area Network System Antenna Location Diagram
(3) Recommended Distribution List

1. The subject analysis was conducted in accordance with reference (a) as requested by reference (b) concerning the HERO impact of installing and operating a WLAN in Hangar 5 at NAS Brunswick, Maine. This request and the system specifications were provided on 6 November 2002. Enclosure (1) provides the system specifications and HERO safe separation distances. Enclosure (2) is a diagram showing the locations of the fixed access points within Hangar 5. Enclosure (3) contains a recommended distribution list.

2. The WLAN system will be installed at multiple locations within Hangar 5. The system includes fixed access point transceivers and client adapter network interface cards installed in a variety of computers throughout the facility. Enclosure (1) provides the system specifications and HERO safe

FILE (REF#)

Subj: **HAZARDS** OF ELECTROMAGNETIC RADIATION TO ORDNANCE (**HERO**)
ANALYSIS FOR THE INSTALLATION OF A WIRELESS LOCAL **AREA**
NETWORK (WLAN) IN HANGAR 5 AT NAVAL AIR STATION (NAS)
BRUNSWICK, MAINE

separation distances. Enclosure (2) is a diagram showing the locations of the fixed access points within Hangar 5.

3. Calculated electromagnetic environments indicate that the antenna placement of the fixed access points listed in enclosure (2) is such that the distance and/or radiation angle with respect to ordnance locations preclude the need for **HERO** emission control (EMCON).

4. **HERO** EMCON will be necessary for the client adapters listed in enclosure (1) whenever ordnance operations occur within the **HERO** safe separation distances provided. EMCON will consist of silencing the offending client adapter,

5 It is recommended that enclosure (1) be incorporated into Appendix A of reference (c), the current **HERO** assessment report for this station.

6. **This project** is recommended for **HERO** approval provided there is adherence to the **HERO** safe separation distances specified in enclosure (1) for the client adapter.

7. **If there** are any questions or comments, please contact Charles Denham, J52, at commercial (540) 653-3444 or DSN 249-3444, or via electronic mail at denhamcc@nswc.navy.mil.

Virginia S Hudson
VIRGINIA S. HUDSON
By direction

8020
Ser J52/1288

SYSTEM SPECIFICATIONS AND
HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE
SAFE SEPARATION DISTANCES

Enclosure (1)

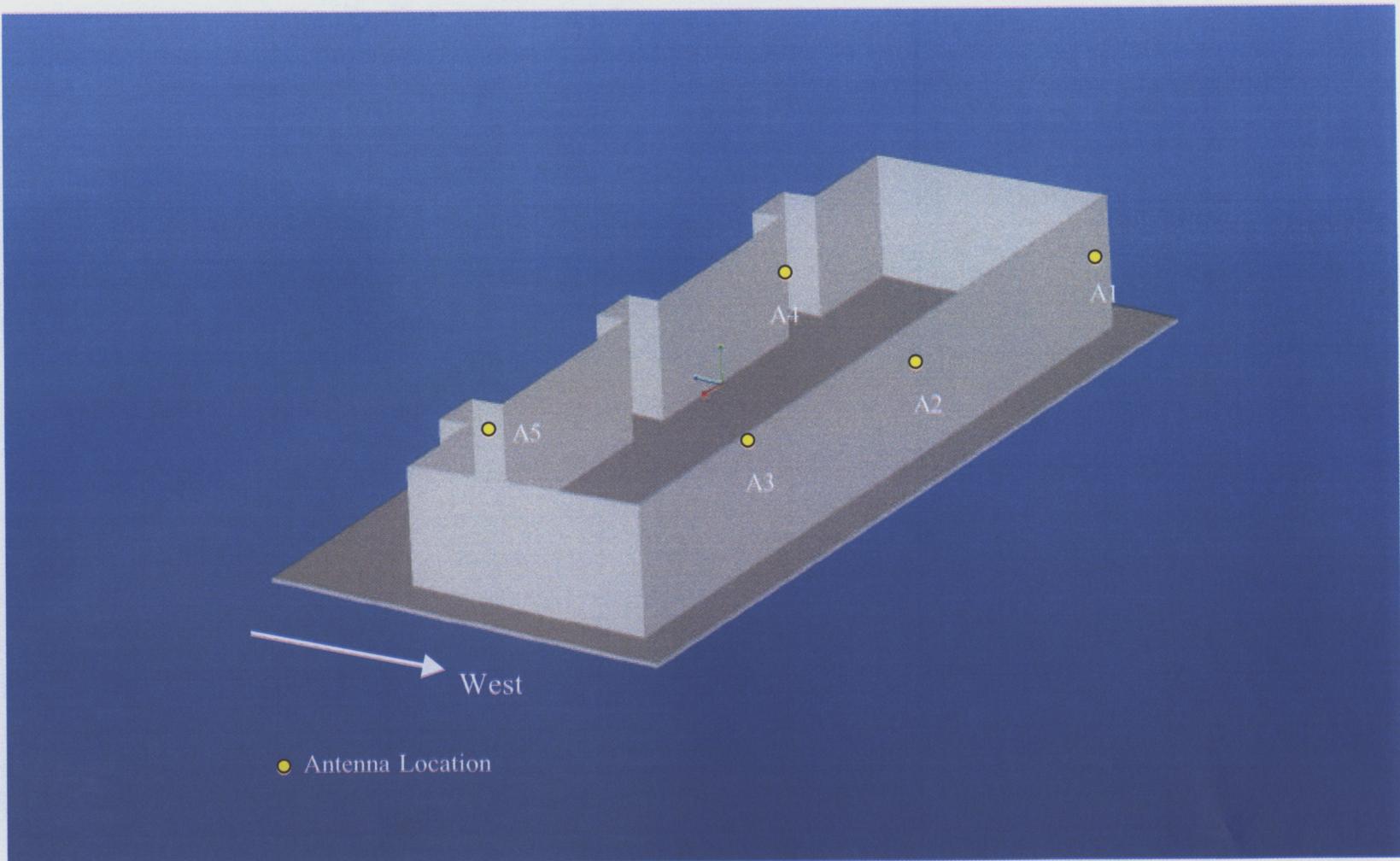
SYSTEM SPECIFICATIONS AND HERO SAFE SEPARATION DISTANCES

| Separation Distances | | | | | | | | |
|----------------------|----------------------|------------------|--------------------|-----------------------------|-------------------------------------|-----------------------------------|------------------------------------|---|
| Antenna Number | Antenna Nomenclature | Antenna Type | Antenna Gain (dBi) | Transmitter Frequency (MHz) | Transmitter Max. Avg. Power (watts) | Transmitter Type | HERO UNSAFE ORDNANCE (feet/meters) | HERO SUSCEPTIBLE ORDNANCE (feet/meters) |
| A1 | AIR-ANT1949 | Yagi | 13.5 | 2400 - 2490 | 0.1 | Cisco Aironet 350 AP | 10/3 | 5/1.5 |
| A2 | AIR-ANT2506 | Omni | 5.2 | 2400 - 2490 | 0.1 | Cisco Aironet 350 AP | 10/3 | 5/1.5 |
| A3 | AIR-ANT1949 | Yagi | 13.5 | 2400 - 2490 | 0.1 | Cisco Aironet 350 AP | 10/3 | 5/1.5 |
| A4 | AIR-ANT3549 | Patch | 8.5 | 2400 - 2490 | 0.1 | Cisco Aironet 350 AP | 10/3 | 5/1.5 |
| A5 | AIR-ANT3549 | Patch | 8.5 | 2400 - 2490 | 0.1 | Cisco Aironet 350 AP | 10/3 | 5/1.5 |
| Mobile PCs | AIR-PCM35x | Diversity Dipole | 1 | 2400 - 2490 | 0.1 | Cisco Aironet 350 Client Adapters | 1/0.3 | 1/0.3 |

8020
Ser J52/1288

HANGAR 5 WIRELESS LOCAL AREA NETWORK SYSTEM
ANTENNA LOCATION DIAGRAM

Enclosure (2)



HANGAR 5 WLAN SYSTEM ANTENNA LOCATION DIAGRAM

8020
Ser J52/1288

RECOMMENDED DISTRIBUTION LIST

Enclosure (3)

**RECOMMENDED DISTRIBUTION LIST FOR HERO ANALYSIS
FOR THE INSTALLATION OF A WLAN IN HANGAR 5 AT NAS BRUNSWICK, ME**

Bath Iron Works
(B. McCue)
700 Washington Street
Bath, ME 04530-2556

Commanding Officer
Naval Air Station
(Safety)
(GEMD)
1251 Orion Street
Brunswick, ME 04011-5009

Commander
Naval Ordnance Safety and Security Activity
Explosives Safety Support Office Atlantic
(N7A)
1282 Gilbert Street
Norfolk, VA 23511-2496

EG&G Technical Services, Inc.
(E. Kuhn)
(HERO Data Base)
16156 Dahlgren Road, P.O. Box 552
Dahlgren, VA 22448-0552

APPENDIX C-2

2000

Ser N1/

From: Commander, Patrol and Reconnaissance Wing FIVE
To: Command Information Systems Security Manager (N62A)

Subj: INTERIM AUTHORITY TO OPERATE SENSITIVE BUT UNCLASSIFIED
WIRELESS INFORMATION SYSTEM

Ref: (a) OPNAVINST 5239.1B
(b) SECNAVINST 5239.3
(c) CINCLANTFLTINST 5239.1A

Encl: (1) System Security Authorization Agreement (SSAA)
(2) Current HERO Certification
(3) SPAWAR E-mail on HERF and HERP Certifications

1. Per references (a) through (c), the Sensitive but Unclassified (SBU) Wireless Telemaintenance Information System within CPRW-5's claimancy is granted an Interim Authority to Operate (IATO) for a period of one year from the date of this document, or until NMCI assumes the project, whichever comes first. During this interim period, a full accreditation determination should be made within CINCLANTFLT or by designated sponsoring activity based upon the completed DITSCAP requirements of enclosure (1), as well as operational test data as evaluated and reported by the sponsoring ONR lab, SPAWAR Systems Center - San Diego.

2. Enclosure (1) is the completed SSAA, enclosure (2) reflects the Wireless Systems' HERO certification, and enclosure (3) reflects SPAWAR's verbal approval of the Wireless Systems' HERP and HERF certifications, documentation forthcoming.

3. This IATO covers the following system:

Hangar 5 North, Wireless Telemaintenance Network, which consists of:

- a. Wearable or portable computers
- b. Wireless 2.4Ghz Client NIC Cards
- c. 2.4Ghz Access Points
- d. Cisco PIX Firewall
- e. Cisco VPN concentrator
- f. Cisco Catalyst LAN Switches
- g. Cisco MCS Call Manager
- h. Cisco Hard IP Phones

Subj: INTERIM AUTHORITY TO OPERATE SENSITIVE BUT UNCLASSIFIED
WIRELESS INFORMATION SYSTEM

- i. Cisco Software Utilities
- j. National Instruments Data Acquisition
- k. Test Cisco 2.4Ghz
- l. Antennas
- m. Miscellaneous portable computer attachments (cameras and headsets and miscellaneous software)
- n. GOTS Windows 2000 Pro software load.

J. C. GRUNEWALD

Copy to: (w/o encl)
VP 8 (CO/ISO/ISSM)
VP 10 (CO/ISO/ISSM)
VP 26 (CO/ISO/ISSM)
VPU 1 (ISO/ISSM)

Additional endorsements to this IATO: (In no particular order)

| Name: | Rank/Code: | Signature: |
|-------|------------|------------|
| | | |
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